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MORPHOLOGICAL LEAF VARIABILITY OF ROWAN (*SORBUS AUCUPARIA* L. EMEND. HEDL. SUBSP. *AUCUPARIA*) IN THE WIELKOPOLSKA NATIONAL PARK

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ABSTRACT. The aim of this study was to describe the variability of leaves of *Sorbus aucuparia* L. Emend. Hedl. subsp. *aucuparia* in the Wielkopolska National Park against the background of environmental conditions. Five populations from different habitats were sampled. In total, 200 compound leaves from sterile short shoots from 100 trees were measured with respect to 12 traits. The biometric data were characterized statistically and subjected to multivariate analyses: analysis of variance (ANOVA/MANOVA), Mahalanobis distances, Jentys-Szaferowa method, and cluster analysis. About two thirds of the correlations between leaf traits are significant. Most traits are characterized by a moderate level of variation. The differences between sampled populations based on leaf traits are statistically significant and related to environmental conditions. Rowan leaves are the biggest on sites with good light conditions and acid soils.

Key words: *Sorbus aucuparia*, Wielkopolska National Park, variability, leaves, multivariate statistical analyses

Introduction

Sorbus aucuparia L. Emend. Hedl. (Rosaceae), called rowan or the European mountain ash, is one of the five so-called primary species of this genus. Its natural range covers most of Europe, Western Siberia, Caucasus, and northern Anatolia (**Meusel** et **al.** 1965). Two of its five subspecies distinguished in Europe (**Warburg** and **Kárpáti** 1968) are found in Poland (**Mirek** et **al.** 2002). The typical *S. aucuparia* L. Emend. Hedl. subsp. *aucuparia* is common nearly throughout Poland, in all forest types and some non-forest habitats. The montane *S. aucuparia* L. Emend. Hedl. subsp. *glabrata* (Wimmer&Grab.) Cajander is limited to the higher zones of the Carpathian and Sudety Mts. Rowan is a valuable biocoenotic species in woodlands, as its succulent red fruit is willingly eaten by birds and mammals.

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In the Wielkopolska National Park, rowan is quite common, found in various habitats: pine forests, pine-oak forests, xerothermic or acid oak forests, oak-hornbeam forests, alluvial forests, at forest edges, and in clearings (**Żukowski** et **al.** 1995).

Research on rowan leaf variability was previously conducted in various forest communities in the Białowieża National Park (**Tyszkiewicz** 1970), in the "Las Piwnicki" reserve near Toruń (**Boińska** and **Nienartowicz** 1979), and in the geographic aspect generally in Poland (**Tyszkiewicz** and **Staszkiewicz** 1997).

The objective of this study was to describe the morphological leaf variability of *S. aucuparia* in various habitats in the Wielkopolska National Park.

Material and methods

Five local rowan populations in various site conditions were selected in the Wielkopolska National Park:

(1) section 1 t, Central European oak-hornbeam forest (*Galio sylvatici-Carpinetum betuli*) on a fresh deciduous forest site (Lśw), lessivé soil;

(2 a) section 4 o, continental oak-pine forest (*Querco roboris-Pinetum*) on a fresh oak-pine forest site (BMśw), podsolic soil proper;

(2 b) section 18 b, continental oak-pine forest (*Querco roboris-Pinetum*) on a fresh oak-pine forest site (BMśw), podsolic soil proper;

(3) section 21 c, suboceanic fresh pine forest (*Leucobryo-Pinetum*) on a fresh coniferous forest site (Bśw), podsolic soil proper;

(4) section 124 a, edge of Central European acid oak forest (*Calamagrostio arundinaceae-Quercetum petraeae*) on a fresh mixed deciduous forest site (LMśw), rusty soil proper.

Leaves from sterile short shoots were collected in the summer of 2004 from 20 trees on each site (two from each tree). From each short shoot, the longest leaf was taken for measurements. Thus a total of 200 leaves from 100 trees were measured. Apart from the traits concerning the whole compound leaf, detailed measurements of the longest leaflet were made (Fig. 1). The following traits were included in the analysis: (A) rachis length; (B) rachis length to lowest pair of leaflets; (C) number of leaflet pairs; (D) longest leaflet length; (E) longest leaflet width; (F) tooth width; (G) number of teeth on leaf margin, (H) number of lateral veins; (I) leaflet length/width ratio; (J) tooth width as percentage of leaf width; (K) location of widest portion of leaflet as percentage of leaflet length; and (L) mean distance between lateral veins.

For each trait, we calculated the arithmetic mean (M), minimum (Min.) and maximum (Max.) values, modal (Mo), standard deviation (SD), and coefficient of variation (CV). Next, coefficients of correlation between traits were assessed. The five local populations were compared graphically by using the Jentys-Szaferowa method of plant shape comparison (**Jentys-Szaferowa** 1959). Significance of differences between the compared populations was evaluated by analysis of variance (ANOVA/MANOVA), Tukey HSD test with separation of homogeneous groups, and Mahalanobis distances. The similarities and differences in studied populations were presented graphically (dendrogram) by use of cluster analysis based on Euclidean distances and the Ward method as an agglomeration method (**Dobosz** 2001).

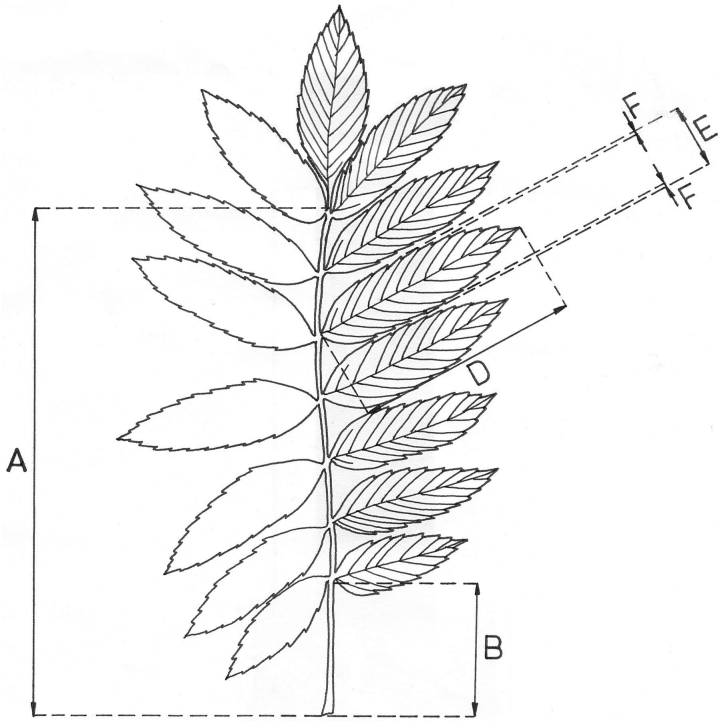

Fig. 1. Method of measuring of the leaves. Features A, B, D-F as on page 14
Ryc. 1. Sposób mierzenia liści. Cechy A, B, D-F jak na stronie 14

Results

Numerical characteristics of leaf variability in rowan for the general sample from the Wielkopolska National Park and from individual local populations (local samples) are presented in Table 1. Rachis length (trait A) varied from 89 to 197 mm (mean 139.08 mm). The first leaflet pair (trait B) appeared usually at 1/4-1/5 of rachis length but this trait varied widely. The compound leaf consisted of 4-8 pairs of leaflets (trait C), but usually of six pairs. Longest leaflet length (trait D) ranged from 38 to 85 mm, while width (trait E) from 13 to 26 mm. The leaf margin had 20-41 teeth of various size (1-4 mm wide). Tooth width accounted for 9.5-40% of leaflet width. Leaflets were densely veined (trait H), with 14 pairs of lateral veins. Distances between veins reached on average 3.94 mm. The leaflets were usually elliptic or ovate, but sometimes obovate. The leaflet length/width ratio was also variable, ranging from 2.24 to about 4.

The least variable traits were: leaflet pair number (trait C), number of teeth (trait G) and number of veins (trait H) on the longest leaflet. The most variable trait was tooth width (trait F); its coefficient of variation exceeded 30%. Leaflets from populations 2 b and 4 had the widest teeth, while those from populations 2 a and 3 had the narrowest teeth. Also tooth width expressed as percentage of leaflet width (trait K) and mean distance between veins (trait L) were highly variable.

Table 1

Arithmetic mean (M), minimum (Min.), maximum (Max), standard deviation (SD) and coefficient of variability (CV) in the general sample, and arithmetic means in local samples of *Sorbus aucuparia*
Średnia arytmetyczna (M), minimum (Min.), maksimum (Max), modalna (Mo), odchylenie standardowe (SD) i współczynnik zmienności (CV) w próbie ogólnej i średnie arytmetyczne w próbach lokalnych *Sorbus aucuparia*

Trait Cecha	General sample – Próba generalna						Local samples – Próby lokalne				
	M	Min.	Max	Mo	SD	CV (%)	1	2 a	2 b	3	4
A	139.08	89.00	197.00	145.00	23.69	17.04	121.06	143.28	139.40	134.91	156.75
B	33.08	17.00	56.00	31.00	7.61	22.99	26.45	33.98	31.36	34.53	39.10
C	6.33	4.00	8.00	6.00	0.66	10.51	6.30	6.30	6.40	6.05	6.58
D	54.48	38.00	85.00	52.00	8.31	15.26	48.95	52.15	54.95	53.23	63.13
E	19.27	13.00	26.00	18.00	2.81	14.58	17.44	18.34	19.49	20.04	21.06
F	4.25	2.00	8.00	4.00	1.34	31.54	4.16	3.45	4.89	3.93	4.84
G	29.63	20.00	41.00	28.00	3.93	13.26	29.90	30.33	28.75	28.70	30.45
H	26.43	17.00	36.00	28.00	2.89	10.94	27.33	26.38	25.40	26.55	26.48
I	2.84	2.24	4.00	2.78	0.31	10.85	2.79	2.84	2.88	2.69	3.00
J	22.03	9.52	40.00	25.00	6.13	27.84	23.68	18.95	25.04	19.64	22.87
K	46.59	20.00	64.58	50.00	6.13	13.17	47.67	49.76	44.82	46.89	43.80
L	3.94	2.00	8.50	3.50	1.06	26.83	3.48	4.04	4.25	3.60	4.35

Among the 66 calculated coefficients of correlation between traits, 41 (62%) were significant (Table 2). Rachis length (trait A) and longest leaflet length and width (traits D and E) were the most strongly correlated with other traits. Location of the widest portion of the leaflet (trait K) was the least correlated with other traits. The strongest positive correlation (r = 0.8864) was observed between tooth width (trait F) and tooth width as percentage of leaflet width (trait J). The strongest negative correlation (r = –0.3296) was found between longest leaflet width (trait E) and leaflet length/width ratio (trait I).

The morphological leaf variability in each population is illustrated in Figure 2, with the use of the Jentys-Szaferowa method. The vertical reference line denotes the arithmetic mean of each trait for the general sample from the Wielkopolska National Park. The comparison of curves indicates that in respect of leaf size (traits A–F), populations from the less fertile sites 2 a, 2 b and 3 are similar to one another and to the mean values of the general sample. Population 1 (from the fertile oak-hornbeam forest) was characterized by the smallest leaves, while population 4 (from acid oak forest) had the largest leaves.

Results of MANOVA attest to significant variation between the studied populations in respect of all 12 traits jointly ($F = 7.40$, $P < 0.05$). One-way analyses of variance (ANOVA) indicate that variation between populations was significant for most traits, except for number of veins (trait H) and leaflet length/width ratio (trait I). The homogeneous groups separated on the basis of the Tukey HSD test show their similarity in respect of individual leaf traits (Table 3).

Table 2

Coefficients of correlation between 12 traits of leaves of *Sorbus aucuparia*
Współczynniki korelacji pomiędzy 12 cechami liści *Sorbus aucuparia*

Trait Cecha	A	B	C	D	E	F	G	H	I	J	K
B	0.7697**										
C	0.4969**	0.1508*									
D	0.7396**	0.6491**	0.2582**								
E	0.5944**	0.4306**	0.1946**	0.7320**							
F	0.1536*	0.0087	0.2317**	0.3057**	0.4801**						
G	0.2205**	0.0792	0.0796	0.2786**	0.1796*	–0.1302					
H	0.2300**	0.1248	0.1736*	0.3442**	0.1924**	0.0234	0.4288**				
I	0.2162**	0.3182**	0.0842	0.3735**	–0.3296**	–0.2583**	0.1644*	0.2056**			
J	–0.1384	–0.2134**	0.1409*	–0.0293	0.0359	0.8864**	–0.2431**	–0.0666	–0.1361		
K	–0.1129	–0.1510*	–0.1115	–0.1251	–0.1248	–0.1731*	0.0710	–0.0140	–0.0168	–0.1316	
L	0.3349**	0.2347**	0.0947	0.3090**	0.3030**	0.1653*	–0.0627	–0.2660**	–0.0013	0.0281	–0.0608

*Significant at the level of 0.05.
**Significant at the level of 0.01.
*Korelacja istotna na poziomie 0,05.
**Korelacja istotna na poziomie 0,01.

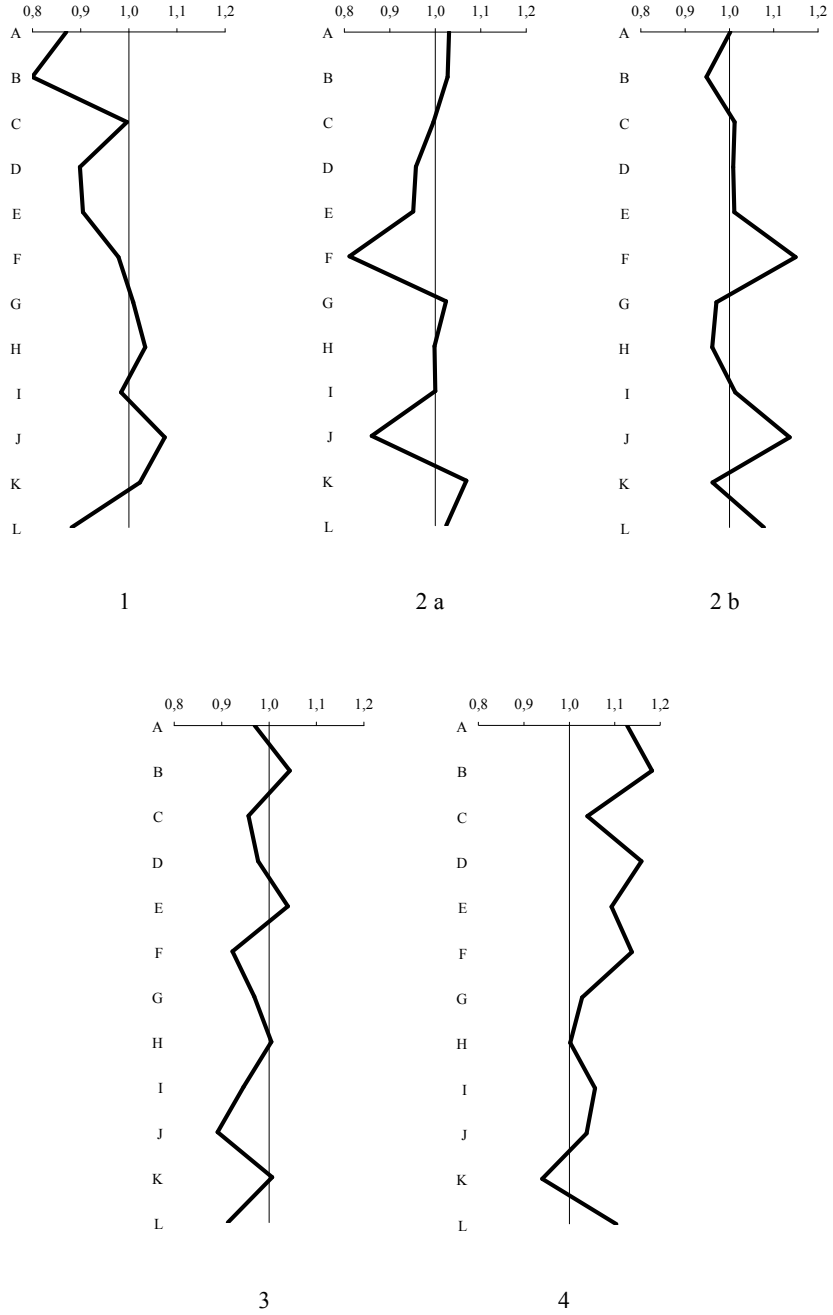

Fig. 2. Lines of size and shape of leaves of five local populations of *Sorbus aucuparia* (angular lines) in comparison with mean values of general sample (vertical lines)
Ryc. 2. Linie wielkości i kształtu cech liści pięciu populacji lokalnych *Sorbus aucuparia* (linie łamane) porównane do średnich wartości cech próby ogólnej (linie pionowe)

Table 3

The results of analysis of variance (ANOVA) defining differentiation of five local populations of *Sorbus aucuparia* in respect to 12 traits of leaves (separately) together with homogeneous groups of populations set on the basis of Tukey HSD test; $F_{0.05} = 2.42$
Wyniki analizy wariancji (ANOVA) przedstawiające zróżnicowanie pięciu populacji lokalnych *Sorbus aucuparia* w odniesieniu do 12 cech liści (oddzielnie) wraz z grupami jednorodnymi populacji wyznaczonymi na podstawie testu Tukeya HSD; $F_{0,05} = 2,42$

Trait – Cecha	$F_{cal.} – F_{obl.}$	Homogeneous groups – Grupy jednorodne
A	15.44	4 2 a 2 b 3 1
B	20.78	4 3 2 a 2 b 1
C	3.45	4 2 b 1 2 a 3
D	23.73	4 2 b 3 2 a 1
E	12.63	4 3 2 b 2 a 1
F	9.84	2 b 4 1 3 2 a
G	1.89	4 2 a 1 2 b 3
H	2.31	1 3 4 2 a 2 b
I	6.16	4 2 b 2 a 1 3
J	8.45	2 b 1 4 3 2 a
K	6.57	2 a 1 3 2b 4
L	5.95	4 2 b 2 a 1 3

Also Mahalanobis distances between the compared populations, calculated on the basis of all traits jointly confirmed the existence of statistically significant differences between the populations (Table 4).

The dendrogram based on the 12 leaf traits (Fig. 3) shows the remarkable similarity between the three populations in pine forests (2 a, 3, and 2 b). The population in oak-hornbeam forest (1) is somewhat similar to them. The most distinct is population 4, found at the edge of acid oak forest.

Table 4

Mahalanobis distances between five populations of *Sorbus aucuparia*
Odległości Mahalanobisa pomiędzy pięcioma populacjami *Sorbus aucuparia*

Population Populacja	1	2 a	2 b	3
2 a	1.6408**			
2 b	2.1782**	2.2042**		
3	2.0688**	1.6833**	2.1264**	
4	2.8756**	2.5292**	1.7208**	2.4298**

**Significant at the level of 0.05.
**Odległości istotne na poziomie 0,05.

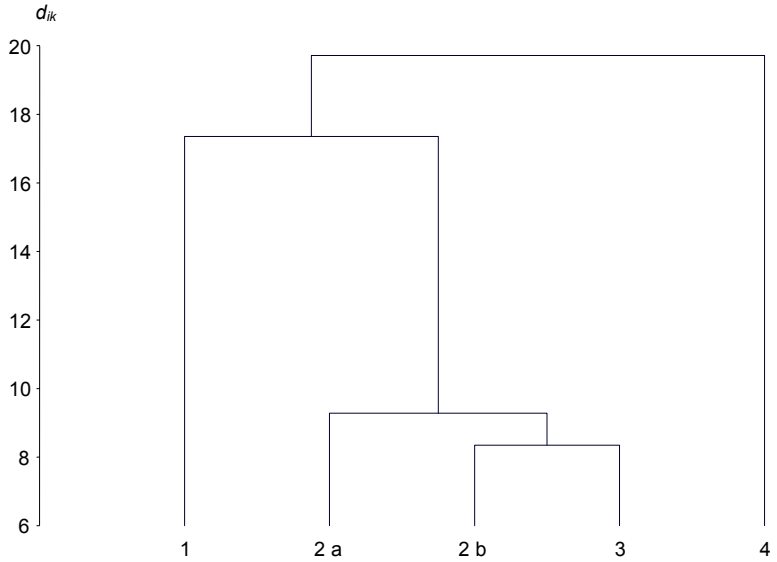

Fig. 3. Dendrogram of similarity of five *Sorbus aucuparia* populations in respect to 12 traits of leaves; d_{ik} – Euclidean distance
Ryc. 3. Dendrogram podobieństwa pięciu populacji *Sorbus aucuparia* pod względem 12 cech liści; d_{ik} – odległość Euklidesowa

Discussion

Ranges of variation of leaf traits of *S. aucuparia* in the Wielkopolska National Park fitted within the ranges of their variation reported for Poland (**Tyszkiewicz** and **Staszkiewicz** 1997). The most variable traits were tooth width (trait F) and tooth width as percentage of leaflet width (trait J), as their coefficients exceeded 30%. This confirms

the results of earlier studies (**Tyszkiewicz** 1970, **Tyszkiewicz** and **Staszkiewicz** 1997). In local populations from the Wielkopolska National Park, these traits were weakly correlated with forest site type, as they differed extremely between populations 2 a and 2 b, occupying forest sites of the same type. The most constant traits, which did not vary significantly between the populations, were numbers of teeth (trait G) and of veins (trait H) on the longest leaflet. On the scale of Poland (**Tyszkiewicz** and **Staszkiewicz** 1997), the most constant trait was longest leaflet width.

The earlier studies on rowan leaf variability in various forest communities in the Białowieża National Park (**Tyszkiewicz** 1970) and the "Las Piwnicki" reserve near Toruń (**Boińska** and **Nienartowicz** 1979) indicated that the variability was clearly related to environmental conditions. According to **Tyszkiewicz** (1970), leaf size and shape were not affected by edaphic factors in the Białowieża National Park, but could be influenced by availability of sunlight. Also **Tyszkiewicz** and **Staszkiewicz** (1997) reported that leaf dimensions in this species depend on the amount of available sunlight. Results of investigations in the Wielkopolska National Park confirm this relationship. Rowan is a light-demanding plant that does not need fertile soils, so it finds more favourable conditions for development in acid soils at the edge of acid oak forest and in the relatively open pine forests than in the fertile but very shaded oak-hornbeam forest.

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ZMIENNOŚĆ MORFOLOGICZNA LIŚCI JARZĘBU POSPOLITEGO (*SORBUS AUCUPARIA* L. EMEND. HEDL. SUBSP. *AUCUPARIA*) W WIELKOPOLSKIM PARKU NARODOWYM

S t r e s z c z e n i e

Celem niniejszej pracy było zbadanie i opisanie zmienności morfologicznej liści *Sorbus aucuparia* L. Emend. Hedl. subsp. *aucuparia* na terenie Wielkopolskiego Parku Narodowego. Do badań wybrano pięć populacji jarzębiny występujących na terenie Parku na stanowiskach zróżnicowanych pod względem siedliskowym. Liście z krótkopędów płonnych zebrano z 20 drzew na każdym stanowisku, po dwa z każdego drzewa. Z każdego krótkopędu brano do pomiarów największy liść. Łącznie więc pozyskano do badań biometrycznych 200 liści ze 100 drzew. Oprócz cech dotyczących całego liścia złożonego, szczegółowymi pomiarami objęto najdłuższy listek na liściu. Analizowano 12 następujących cech: A – długość osadki, B – długość osadki do pierwszej pary listków, C – liczba par listków, D – długość najdłuższego listka, E – szerokość najdłuższego listka, F – szerokość ząbkowania, G – liczba ząbków, H – liczba nerwów, I – stosunek długości listka do jego szerokości, J – szerokość ząbkowania w procentach szerokości blaszki, K – położenie najszerszej części listka w procentach długości blaszki, L – przeciętna odległość nerwów bocznych. Dla poszczególnych cech obliczono średnie arytmetyczne (M), wraz z ich charakterystykami, takimi jak: wartości skrajne (Min. i Max), modalna (Mo), odchylenie standardowe (SD) i współczynnik zmienności (CV). Obliczono również współczynniki korelacji pomiędzy wartościami poszczególnych cech. Populacje lokalne porównano graficzną metodą Jentys-Szaferowej. Istotność różnic pomiędzy porównywanymi populacjami określono na podstawie przeprowadzonej analizy wariancji (ANOVA/MANOVA), testu Tukeya HSD z wydzieleniem grup jednorodnych oraz obliczonych odległości Mahalanobisa. Podobieństwa i różnice badanych populacji przedstawiono też graficznie (dendrogram), wykorzystując analizę skupień, przyjmując odległość Euklidesową jako miarę odległości i metodę Warda jako metodę aglomeracji.

Najbardziej stałymi cechami okazały się liczba par listków (cecha C) oraz liczba ząbków (cecha G) i liczba nerwów (cecha H) na największym listku. Najbardziej zmienną cechą jest szerokość ząbkowania (cecha F). Większość cech charakteryzuje się średnim poziomem zmienności. Spośród 66 współczynników korelacji obliczonych pomiędzy wartościami cech biometrycznych liści 41 (62,12%) jest statystycznie istotnych. Wykazano, że badane populacje różnią się statystycznie istotnie pod względem 12 cech liści łącznie oraz że różnice między liśćmi pochodzącymi z pięciu populacji są związane z warunkami siedliskowymi. Największe liście występują u jarzębin rosnących w dobrych warunkach świetlnych i na kwaśnych glebach.

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